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Estimates of willingness to accept compensation to manage pine stands for ecosystem services

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ABSTRACT

Many ecosystem services are often overlooked in active management of private forests leading to their production below the levels preferred by the society. This study used the contingent valuation method (CVM) to estimate willingness to accept (WTA) compensation for managing a hypothetical tract of loblolly pine (*Pinus taeda*) for multiple ecosystem services. The CVM scenario involved four forest management alternatives representing increasing levels of forest management restrictions. A structural random effects probit model was constructed to quantify WTA compensation amounts. Mean WTA estimates ranged from $190.22 to $595.23 per hectare (ha) per year and increased with the intensity of forest management restrictions. Based on the WTA estimates, the total cost of increasing ecosystem production ranged from $0.88 to $4.76 billion per year. Increased budgets and private partnerships might be needed to implement forest management regimes facilitating multiple ecosystem services.

1. Introduction

Ecosystem services have been receiving increased attention because of their role in enhancing human welfare through the provision of numerous commodities and benefits such as food, clean water, clean air, carbon sequestration, and recreation (Chapman et al., 2017; Costanza et al., 2014; Millennium Ecosystem Assessment, 2005; De Groot et al., 2002; Costanza et al., 1997). In the southern United States, a substantial portion of ecosystem services is provided by family forests which account for 70% of the total forest land area in the region (USDA Forest Service, 2009). Therefore, private forest lands have the potential to supply many ecosystem services and private landowner willingness to manage their land for these services will be crucial in sustaining many social and economic needs of the growing population in the region (Benayas et al., 2009).

Conservation attempts to increase production of ecosystem services from private forest lands have been challenging because of the non-market nature of many such services and the need to enlist a voluntary involvement of private landowners under increasing budgetary limitations (Kline et al., 2013). Due to the non-market character of ecosystem services, family forest landowners are often not motivated to actively implement forest management practices facilitating the provision of these service because they are not compensated for doing so (Calow, 2017; Grebner et al., 2013). Landowners might also be hesitant to actively manage forests for ecosystem services because of potentially increased forest management costs, forgone timber income, and because such management practices may not be consistent with their forest ownership goals (Kilgore et al., 2007; Mozumder et al., 2007). Furthermore, limited information on the monetary value of ecosystem services or lack of it, hinders decisions related to prioritization of conservation practices and development of incentive programs facilitating their provision (Wright et al., 2017; Calow, 2017). As a result, it is difficult to ensure that regional conservational priorities are consistent with family forest landowner objectives and that ecosystem services are provided at socially-preferred levels (Galik and Grala, 2017). Economic valuation of ecosystem services is, therefore, necessary to determine the monetary cost of their provision, inform future budget allocations, and help prioritize conservation efforts focused on increased provision of ecosystem services (Campbell and Brown, 2012; Kreuter et al., 2006). While monetary valuation of ecosystems services has been serving as an important tool in developing policies aiming at increasing supply of ecosystem services, other strategies such as taxes or command and control instruments can also be implemented to improve their provision (Engel et al., 2008). Thus, a combination of various policy instruments might be needed to achieve a socially-preferred level of ecosystem services (Makkonen et al., 2015).

Various methods have been used to monetarily evaluate ecosystem services and they can be generally grouped into two categories: stated

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and revealed preference methods (Clark and Friesen, 2008). The contingent valuation method (CVM) is the most-commonly used stated preference approach, and involves estimation of monetary value through the use of hypothetical scenarios presented to respondents (Chien et al., 2005; Dupraz et al., 2003; Cooper et al., 2002; Cummings et al., 1995). The CVM is typically based on the use of maximum willingness to pay (WTP) for a marginal improvement in environmental quality or access to a specific nonmarket good or benefit (Mitchell and Carson, 2013; Kling et al., 2012; Wossink and Swinton, 2007; Hanley et al., 2003; Arrow et al., 1993). However, the CVM can also use a minimum willingness to accept (WTA) approach to quantify monetary amounts to compensate individuals for sustained environmental losses or providing non-market goods or benefits (Small et al., 2017; Arrow et al., 1993) in situations where the property rights for the good or benefit in question lie with the respondent and are well defined (Del Saz-Salazar et al., 2009). Nevertheless, the CVM has been criticized for a number of perceived weaknesses that include, among others, the failure of respondents to incorporate their personal budgets in valuation decisions, embedding effect, and overestimation of values that might undermine the credibility of derived monetary estimates (Hausman, 2012, Diamond and Hausman, 1994). Thus, various studies have called for the need to validate CVM by examining its consistency with economic theory (Haab and McConnell, 2002, Carlsson and Martinisson, 2001).

In the absence of monetary compensation, many forest landowners might be hesitant to manage their forests for ecosystem services beyond their own needs (Cooley and Olander, 2011). However, they might be willing to produce ecosystem services at socially-preferred levels if sufficient monetary incentives are provided (Zhang, 2016). Thus, the WTA approach can be used to determine minimum compensation levels needed to induce private forest landowners to increase production of multiple ecosystem services as well as quantify their provision cost and determine budgets required to implement conservation activities facilitating these services at regional levels.

Many previous studies used the WTA approach to quantify the monetary value of different ecosystem services (Bergstrom and Ready, 2009; Nahuelhual-Muñoz et al., 2004). Some of these studies were related to landowner management preferences and involved determination of the monetary compensation necessary to induce landowners to implement forest management activities facilitating various ecosystem services such as aesthetics, biomass production, carbon sequestration, hunting, and recreational access (Timmons, 2014, Erickson et al., 2011, LeVert et al., 2009, Kilgore et al., 2008, Loomis et al., 2000, Kline et al., 2000). Reported monetary compensation estimates varied substantially. For example, Kilgore et al. (2008) reported that a minimum of \$59.29/ha was necessary to encourage Minnesota landowners to participate in the Sustainable Forest Initiative (SFI) program focused on enhancing water quality and wildlife habitat. Timmons (2014) found that as much as \$793.05/ha was required by landowners to produce biomass for bioenergy purposes in Massachusetts. However, compensation as high as \$1729/ha/year was required by landowners in Massachusetts and Vermont to conserve forests in perpetuity to produce a variety of ecosystem services (LeVert et al., 2009). Observed variations in the expected level of compensation among family forest owners were influenced by both economic and non-economic factors (Erickson et al., 2011). Economic aspects might be linked to foregone income streams associated with restrictive forest management strategies, whereas non-economic factors might include, for example, landowner's goal to purse recreational activities (Erickson et al., 2011; Matta et al., 2009; LeVert et al., 2009; Joshi and Arano, 2009; Janota and Broussard, 2008; Kreuter et al., 2006; Kline et al., 2000). Thus, successful efforts to encourage production of ecosystem services among family forest owners will require a better understanding of the financial and non-financial factors influencing their forest management decisions.

Although a large number of studies were conducted to quantify the monetary cost of providing ecosystem services in the southern United States (e.g., Timmons, 2014, Joshi et al., 2013, Hite et al., 2002, Gruchy et al., 2012, Gunter et al., 2001), many of them focused on individual ecosystem services such as wildlife habitat, carbon sequestration, and biomass production. However, such an approach can potentially underestimate the cost necessary to sustain forest resources that produce multiple ecosystem services (LaRocco and Deal, 2011). This is because other valuable ecosystem services produced by forests are not taken into consideration and might lead to their insufficient production (Cooley and Olander, 2011). Furthermore, when quantifying the compensatory cost of providing ecosystem services, probit and logit regression models, implicitly assuming landowners as a homogenous group, were commonly used (Lynch and Lovell, 2003). However, forest landowners differ substantially in terms of their sociodemographic characteristics and ownership priorities (Butler et al., 2017, Kluender and Walkingstick, 2000). Thus, assuming that forest landowners could be considered as a homogenous group might have led to inaccurate estimates (Nahuelhual-Muñoz et al., 2004).

The primary objective of this study was to estimate the minimum amount of monetary compensation necessary to induce family forest owners in Mississippi to implement forest management practices facilitating an increased production of multiple ecosystem services by pine forests managed for timber production. The focus on intensively-managed pine stands was motivated by four factors. First, loblolly-shortleaf and longleaf-slash pine forests account for 40.9% of a forest land area in Mississippi with loblolly-shortleaf pine being the most common (37.0%) forest-type group (Oswalt, 2013). Loblolly-shortleaf pine and longleaf-slash forests also account for 32.0% of non-corporate private forest land area in the southeastern United States (Oswalt et al., 2014). Second, pine forests provide numerous ecosystem services including habitat for > 20 protected species (NRCS Mississippi, 2018) and these ecosystem services can be enhanced by delayed harvests (Grebner et al., 2013). Third, there have been substantial restoration efforts to increase the area of longleaf pine (*Pinus palustris*) forests in the southern United States, which provide numerous ecosystem services but typically are characterized by rotation ages shorter than loblolly pine (*Pinus taeda*) (Hanberry et al., 2018; NRCS Mississippi, 2018). By determining landowner willingness to delay final harvest, it will possible to determine the likelihood of increasing production of stackable ecosystem services not only by loblolly pine stands but also by restoring native tree species requiring longer rotations such as longleaf pine (LaRocco and Deal, 2011; Gürlük, 2006). Fourth, forest landowners in the region have been facing decreasing timber prices and 46% of surveyed landowners were willing to delay a harvest due to economic outlook. Thus, income from ecosystem services can help them mitigate market fluctuation and potentially offset timber revenue losses. This study used a structural random effects probit model to account for landowner differing socioeconomic characteristics and forest ownership goals to derive WTA estimates that can be used as an indication of potential budgets needed to implement future incentive programs to increase provision of ecosystem services (LaRocco and Deal, 2011), determine the total value of forests (Nesbitt et al., 2017), and guide future policy changes related to a long-term forest use compared to other non-forest uses (Matta et al., 2009), and prioritize future conservation approaches in regions with predominantly private ownership (Kilgore et al., 2008).

2. Methods

2.1. Study site description

This research was conducted in Mississippi, located in the southern United States. Mississippi was selected as a study site because of substantial area of pine forests managed for timber production and a comparable proportion of family forest owners to other states in the southern United States (Butler, 2008). Information sourced from the U.S. Census Bureau (2012) indicated that Mississippi had a total land surface of 12.5 million hectares (ha). Forests accounted for eight million ha, of which 70% was owned by 315,000 family forest landowners (USDA Forest Service, 2009; Gordon et al., 2013). Three key forest types include pine, hardwood, and mixed pine-hardwood forests (USDA Forest Service, 2009; Southeast Mississippi Forest Inventory Report, 2006). Loblolly-shortleaf forest stands are the most common forest-type group (2.9 million ha) in Mississippi, followed by oak-hickory (2.1 million ha), oak-gum-cypresses (1.0 million ha), oak-pine (0.9 million ha), elm-ash-cottonwood (0.5 million ha), and longleaf-slash (0.3 million ha) as well as other forest-type groups covering approximately 0.1 million ha (Oswalt, 2013). The state's forest industry economic impact including direct, indirect, and induced effects was estimated at $10.4 billion in 2013 (Dahal et al., 2013).

2.2. Data collection methods

A total of 2025 structured questionnaires were mailed between July and August in 2012 to family forest landowners in Mississippi, whose names were obtained from a commercial provider and were originally identified based on tax rolls. The mail survey was implemented using the Dillman's Total Design Method which consisted of a five-stage mailing process involving an initial letter to landowners to explain the study objectives, a letter with a survey questionnaire, a thank you/reminder postcard, and two follow-up letters with questionnaires (Dillman, 2011).

A CVM scenario included in the questionnaire was designed following an approach used by Nahuelhual-Muñoz et al. (2004). To reflect the research focus on intensively-managed pine stands, a hypothetical valuation scenario was developed in which landowners were asked to assume they owned a 16.2 ha (40 acres) tract of a 25-year old loblolly pine (*Pinus taeda* L.) stand managed for timber and that they were planning to harvest the stand at the end of 2012 (year when the survey was deployed). Then, landowners were presented with an opportunity to participate in a hypothetical Conservation Reserve Program (CRP) administered by U.S. Department of Agriculture (USDA). Under the program agreement, landowners were required to defer harvest by 10 years in exchange for an annual payment. In the CVM scenario, a ten-year period was used to reflect current obligations under the USDA's CRP that offers 10- to 15-year contracts (USDA NRCS 2014). The scenario involved four forest management alternatives representing increasing levels of forest management restrictions. These forest management alternatives were assumed to gradually enhance provision of ecosystem services and increase their diversity due to the differing levels of management intensity and types of implemented management prescriptions as indicated by Lockhart et al. (2006) and Kahl and Bauhus (2014). The alternatives presented to landowners included:

Management Alternative A: Harvest at the end of 2012. In this alternative, a landowner would harvest the loblolly pine tract as initially planned at end of 2012. As a result, a landowner would not participate in the CRP and would not receive an annual payment. For analysis purposes, this management alterative was set as the baseline scenario.

Management Alternative B: Delayed harvest with all silvicultural activities allowed. In this alternative, a final harvest of the loblolly pine tract was delayed for 10 years to the end of 2022. However, the landowner was permitted to conduct all timber stand improvement (TSI) activities to produce timber including partial harvests, commercial thinnings, tree release, prescribed burnings, and sanitation activities.

Management Alternative C: Delayed harvest with only some silvicultural activities allowed. In this alternative, a final harvest of loblolly pine stand was delayed for 10 years to the end of 2022. The landowner was allowed to conduct light thinnings of the stand and other silvicultural practices but only if they enhanced provision of ecosystem services. Such management activities included prescriptions promoting game and non-game wildlife habitat, creating openings, implementing a prescribed burning, and implementing sanitation activities for good forest health. A consulting forester would provide guidance related to the forest management plan and related activities.

Management Alternative D: Delayed harvest with no silvicultural activities allowed. In this alternative, a final harvest of loblolly pine stand was delayed for 10 years to the end of 2022. During this time, a landowner was not permitted to thin the stand or carry out any TSI activities except for sanitation activities for safety reasons and achieving forest health.

After the description of forest management alternatives, a landowner was presented with three discrete choice questions constructed as follows:

> "Would you manage your 40-acre loblolly pine tract according to Management Alternative B (delayed harvest with all silvicultural activities allowed) instead of Management Alternative A (harvest at the end of 2012) if you were offered an annual payment of $___per acre for the duration of 10-year contract?"

The landowner was given three possible responses to the question: yes, no, and unsure. Two subsequent questions presented to landowners focused on alternatives C and D, respectively, with each being compared to a baseline alternative A. Fifteen bid amounts were used to elicit landowners WTA compensation for implementing the proposed forest management alternatives: $1, $3, $5, $8, $12, $20, $30, $40, $50, $60, $80, $100, $120, $150, and $200 per acre (ac) per year for 10 years. Bid amounts were originally presented to landowners on per ac basis and later recalculated on per ha basis. To assess variation in landowner forest management preferences, all three questions involved the same bid level which was randomly assigned to 15 groups of landowners with 135 landowners in each group. Bid amounts were determined based on the literature and consultation with Extension personnel in the College of Forest Resources at Mississippi State University.

2.3. Analytical framework

Following Arano et al. (2004), a random utility model was adopted where landowner's utility from a particular forest management alternative i was specified as:

$$U_i = U_i(y_i, z, \varepsilon_i) \tag{1}$$

where y_i represents timber and non-timber income from a forest management alternative i; z is a vector of landowner socioeconomic characteristics such as gender, age, education, familiarity with CRP, previous management of a forest land for ecosystem services, membership in professional organizations, possession of a written forest management plan, annual household income in 2011, importance of legacy for heirs as a forest ownership goal, importance of personal recreation as forest ownership goal, importance of a long-term investment as a forest ownership goal, past enrollment of forest land in a federal conservation program, and forest land characteristics such as forest land area owned; and ε_0 is the error term for unobserved factors.

Participation in forest management alternatives *B, C,* and *D* involved an increasing level of forest management restrictions in exchange for an annual compensation payment w_i. It was thus assumed that a landowner would be in favor of alternative forest management plan $j \neq 0$ if and only if:

$$U_j(y_j + w_j, z, \varepsilon_j) > U_0(y_0, z, \varepsilon_0) \tag{2}$$

where U_j is a linear utility function associated with forest management alternative $j \neq 0$ (i.e., forest management alternative B, C, or D, respectively) and compensation payment w_j, and U_0 is the linear utility function associated with the baseline forest management alternative A.

If the utility associated with a particular forest management alternative is greater than the baseline alternative, the landowner would elect to implement it because it would make her/him better off in terms of welfare. Each alternative was assigned a value of "1" when a landowner agreed to implement it or "0" if a landowner was not willing to implement it. Discrete choice models can be used to determine factors that influence the choice of each alternative (Lynch and Lovell, 2003). However, Petrolia and Kim (2009) and Greene (2007) noted that probit models may be correlated through error terms because heterogeneous choice decisions are constructed within the context of the same survey data. As such, they suggested the use of a structural random effects probit model for cross sectional data. Following Cappellari and Jenkins (2003), the model was formulated as:

$$\gamma_i^* = \alpha_i X_i + e_{it}$$
$$Y_i = 1, \text{ if} \gamma_i^* > 0 \quad (3)$$

where γ_i^* is the unobserved latent variable and Y_i is the observed outcome; $Y_i = 1$ relates to the landowner choice to implement a forest management alternative B, C or D (implying $U_j > U_0$) and $Y_i = 0$ (implying $U_j < U_0$) otherwise; α_i is a partial regression coefficient; X_i represents the set of independent sociodemographic and economic variables (Table 1); and e_{it} is the error term which is multivariate normal, identically, and independently distributed (iid).

In addition:

$$e_{it} = q_i + u_{it} \quad (4)$$

where the error term (e_{it}) can be disentangled into q_i representing the individual specific effect due to heterogeneity among landowners and u_{it} representing the error term due to unexplained variation.

Furthermore, the variance of the term was represented by:

$$\delta_i^2 + \delta_{it}^2 \quad (5)$$

As such, the correlation coefficient of error terms was given by:

$$\frac{\delta_v^2}{1 + \delta_v^2} \quad (6)$$

In total, two random effects probit models were estimated. This was necessitated by the fact that there is no agreement regarding the treatment of unsure responses (Hwang et al., 2014; Groothuis and Whitehead, 2002). In model 1, responses of landowners who were unsure if they would implement proposed forest alternative featuring management restrictions were removed from the analysis. In model 2, "unsure" responses were treated as "no" responses. It was also possible to develop an alternative model in which "unsure" responses were treated as "yes" responses (Groothuis and Whitehead, 2002). However, answers to a debriefing question revealed that most unsure landowners would not accept the proposed management alternatives indicating that a model in which "unsure" responses were treated as "yes" would not be consistent with respondent opinions.

2.3.1. Model diagnostics

Previous econometric studies (Wilde, 2000) have indicated that model identification is achieved if there is sufficient variation in the survey data. Therefore, in the context of the system of equations, there may be no need to subject the model to a set of formal instruments to evaluate identification process since there were no endogenous variables on the right-hand side of the equations (Roodman, 2011). Instead, the regressors included in the models were informed by the conceptual framework. Literature, however, points out that heteroscedasticity represents a more serious issue (Roodman, 2011). To generate consistent estimators and correct for the presence of heteroscedasticity, robust standard errors were used. Furthermore, bootstrapping of the model helped to increase parameter efficiency. The likelihood ratio (LR) test was used to evaluate significance of the structural random effects regression models (Kutner et al., 2005) and finalize model specification. Additional LR tests were conducted to determine if using a constrained model would improve a model fit by equating similar regression parameters in the model (Hox and Bechger, 1998; Savalei and Kolenikov, 2008). Furthermore, a *t*-test was used to determine individual pairwise differences across parameters. The covariance matrix was used to determine whether there were highly correlated predictor variables in the system of equations.

The econometric models were generated using Stata Version 13 and utilized the user-written complex mixed processes "cmp" routine which is used in cases where three or more equations are jointly estimated (Greene, 2007). Cappellari and Jenkins (2003) suggested using a number of draws equal to the square root of an effective sample size (663 cases); therefore, 25 replications were used. Furthermore, the null hypothesis indicating that error terms were equal to each other was used to evaluate if the structural random effects regression model was

Table 1
Description of dependent and independent variables included in the structural random effects probit model to determine association of socioeconomic factors with Mississippi's family forest landowner willingness to accept (WTA) compensation to manage a forest for ecosystem services based on a mail survey conducted in 2012.

Variable	Variable description
Dependent	
WTA vote	Landowner's willingness to implement a forest management alternative facilitating ecosystem services. A binary variable: 1 if a landowner voted "yes" to implementing a proposed alternative at an offered payment level; 0 if a landowner voted "no."
Independent	
BID	Bid amount ($/ha/year).
FAM.CRP	Landowner's familiarity with the Conservation Reserve Program (CRP). A binary variable: 1if a landowner was familiar with CRP, 0 if a landowner was not familiar of CRP.
GENDER	Gender. A binary variable: 1if male landowner, 0 if female landowner.
AGE	Age (years).
EDUC	Education level. A binary variable: 1 if at least Bachelor's degree or higher, 0 if lower than Bachelor's degree.
ESPRODN	Previous management of a forest for ecosystem services. A binary variable: 1 if a forest tract was previously managed for ecosystem services, 0 if no.
ENVORG	Membership in environmental organizations: A binary variable:1 if a landowner was a member of an environmental organization, 0 if a non-member.
PROFORG	Membership in professional organizations. A binary variable:1 if a landowner was a member of a professional organization, 0 if a non-member.
FMP	Forest management plan. A binary variable: 1 if a landowner had a written forest management plan, 0 if did not.
INC	Gross annual household income in 2011 before taxes scaled by 1000 ($).
INVEST	Importance of investment as a forest land ownership goal. A binary variable: 1 if a long-term investment was ranked by a landowner as an important forest ownership objective, 0 if was not.
LEGACY	Importance of legacy as a forest land ownership goal. A binary variable: 1 if legacy to heirs was ranked by a landowner as an important forest ownership goal, 0 if was not.
P.RECR	Importance of personal recreation as a forest land ownership goal. A binary variable: 1 if personal recreation was ranked by a landowner as an important forest ownership goal, 0 if was not.
FOREST SIZE	Total forest land area owned scaled by 10 (ha).

an appropriate specification (Greene, 2007). The Krinsky-Robb procedure was used to calculate confidence intervals around the estimated mean WTA compensation amounts (Zander et al., 2014). The mean WTA amounts were calculated using the following formula:

$$mean\ WTA = \frac{\bar{X}_i \beta_i}{\beta_0} \tag{7}$$

where β_0 is the coefficient associated with the bid, β_i represents an estimated coefficient, and $\overline{X_i}$ is a mean of the explanatory variable.

A minimum of 5000 simulations were recommended by Haab and McConnell (2002) to generate precise parameter estimates. A total of 20,000 simulations were used in this study to calculate mean WTA compensation amounts and corresponding intervals.

3. Results

3.1. Non-response bias

A non-response bias was tested by following a procedure suggested by Nybakk et al. (2009) and Armstrong and Overton (1977), involving comparing 10 socioeconomic characteristics between the first and last 10% of landowners in the sample. A group of the last 10% of responding landowners was used as a proxy for landowners who did not return their questionnaires. Additionally, survey sample statistics related to landowner socioeconomic characteristics were compared to summary statistics reported in the National Woodland Owner Survey (NWOS) (Butler, 2008). Comparisons were conducted using a *t*-test as suggested by Nybakk et al. (2009). After accounting for survey questionnaires that were not returned, those involving deceased landowners, and refusals, the adjusted response rate was 37.1%. A non-response bias was not detected after comparing 10 characteristics of respondents and non-respondents ($p > 0.05$). Sample socioeconomic characteristics were also consistent with results from the NWOS.

3.2. Willingness to manage forest for production of ecosystem services

The proportion of landowners willing to implement forest management alternatives facilitating production of ecosystem services increased with higher bid levels (Table 2). Only a small proportion of landowners were willing to implement any of the three forest management alternatives at relatively low compensation levels. For example, at $2.47/ha/year, only 3, 6, and 0% of landowners were willing to implement forest management alternatives B, C, and D, respectively. When a monetary compensation level was increased to $247.05/ha/year, 37% of landowners would implement alternative B, 49% alternative C, and 29% alternative D. However, if the monetary compensation level was further increased to $494.10/ha/year, the percentage of landowners willing to implement management alternatives B, C, and D was 41, 33, and 29%, respectively. Overall, 24% of landowners were willing to implement alternative B, 21% alternative C, and only 13% alternative D at offered payment levels. Results from one-way ANOVA indicated that percentages of landowners willing to implement each forest management alternative were statistically different from each other ($p < 0.05$).

There were numerous reasons reported by landowners for ‘no" and “unsure” responses to implementing proposed alternatives featuring forest management restrictions at offered compensation levels. Most landowners did not support the idea of forest management restrictions (73%). In addition, 62% of landowners indicated that there were not interested in active forest management for ecosystem services. About 54% of landowners did not like long-term nature of forest management alternatives associated with the program, whereas about 26% of landowners were of the opinion that such a program would not be implementable. Approximately 21% of landowners indicated that an offered compensation was not sufficient for participation in the program. However, there was a large proportion of landowners (46%) who were likely to delay a harvest, even in the absence of payments, due to current timber prices and future economic outlook. Only 23% of landowners would harvest their pine stand immediately in the absence of annual payments, whereas 32% were neutral.

3.3. Determinants of willingness to accept compensation

LR results indicated that a structural model was significantly better than using independent probit models ($p < 0.05$). Furthermore, individual pairwise test of parameters across equations indicated that they were statistically different from each other ($p > 0.05$) except for “ecosystem service production” and “membership in environmental organizations.” The Akaike Information Criterion (AIC) of the constrained model was 797.61 and lower than that of the unconstrained model (804.67). However, the likelihood ratio test indicated no significant difference between the two models ($\chi^2 = 0.93$, $p = 0.92$).

Table 2
Landowner’ preferences for forest management alternatives facilitating ecosystem services by a bid amount, derived from a 2012 survey of family forest landowners in Mississippi.

Bid[a] ($/ha/yr)	Total number of responses	Alternative B: “Would delay harvest with all silvicultural activities”		Alternative C: “Would delay harvest with some silvicultural activities”		Alternative D: “Would delay harvest with no silvicultural activities”	
		Number of “yes” responses	Percentage of responses (%)	Number of “yes” responses	Percentage of responses (%)	Number of “yes” responses	Percentage of responses (%)
2.47	39	1	3	2	6	0	0
7.41	39	4	10	3	8	0	0
12.35	51	4	8	4	8	1	2
19.76	41	6	15	4	10	2	5
29.65	43	7	16	4	9	4	9
49.41	50	5	11	6	13	3	6
74.12	39	11	28	10	26	5	13
98.82	35	8	23	6	17	4	11
123.53	46	12	26	9	20	2	4
148.23	48	18	38	15	31	9	19
197.64	48	15	31	16	33	8	17
247.05	41	15	37	20	49	12	29
296.46	46	16	35	14	30	7	15
370.58	45	15	33	9	20	5	11
494.10	51	21	41	17	33	14	29

[a] Original bid levels were expressed in $ per acre per year and involved the following amounts: $1, $3, $5, $8, $12, $20, $30, $40, $50, $60, $80, $100, $120, $150, and $200.

Table 3

Structural random effects probit regression model results on the association of socioeconomic and demographic characteristics with Mississippi's family forest landowner willingness to implement forest management alternatives facilitating ecosystem services with "unsure" responses removed (model 1), based on a mail survey conducted in 2012.

	Delayed harvest with all silvicultural activities allowed (B)			Delayed harvest with some silvicultural activities allowed (C)			Delayed harvest with no silvicultural activities allowed (D)		
	Coef.	Rob. S.E	M.E	Coef.	Rob. S.E	M.E	Coef.	Rob. S.E	M.E
INC	0.003	0.004	0.003	0.004	0.004	0.001	−0.002	0.004	−0.003
AGE	0.000	0.006	0.000	−0.004	0.007	−0.001	0.004	0.007	0.001
EDUC	−0.085	0.337	−0.028	−0.210	0.547	−0.071	−0.071	0.610	−0.021
GENDER	0.347*	0.206	0.111	0.230	0.214	0.077	0.319	0.229	0.095
PROFORG	0.173	0.172	0.057	0.370**	0.173	0.125	0.030	0.180	0.009
ENVORG	0.218	0.381	0.072	−0.381	0.456	−0.129	−0.206	0.485	−0.061
FMP	0.306	0.193	0.101	0.228	0.187	0.072	−0.004	0.202	−0.001
FAM.CRP	0.228	0.169	0.075	0.185	0.167	0.062	0.177	0.173	0.053
BID	0.003**	0.000	0.010	0.002**	0.000	0.090	0.002**	0.000	0.070
LEGACY	0.033	0.440	0.100	0.221	0.433	0.007	−0.089	0.430	−0.02
P.RECR	0.247	0.378	0.081	0.169	0.367	0.057	0.202	0.393	0.060
ESPRODM	−0.001	0.204	−0.004	−0.090	0.188	−0.030	−0.195	0.220	−0.058
FOREST SIZE	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
INVEST	0.990**	0.393	0.327	0.873**	0.398	0.295	0.650	0.403	0.195
Constant	−2.678	1.046		−1.792	1.021		−2.172	1.105	
Log likelihood	−350.31								
P-value	0.000								
atanhrho_12	1.441**								
atanhrho_13	1.236**								
atanhrho_23	1.562**								
N = 463									

Coef.: Coefficient; Rob. SE: Robust Standard Error; M.E: Marginal Effect.

* Significant at 10%.

** Significant at 5% level.

Table 4

Structural random effects probit model regression results on the impact of socioeconomic and demographic characteristics on Mississippi's family forest landowner willingness to implement forest management alternatives facilitating ecosystem services with "unsure" responses coded as "no" responses (model 2), based on a mail survey conducted in 2012.

Variable	Delayed harvest with all silvicultural activities allowed (B)			Delayed harvest with some silvicultural activities allowed (C)			Delayed harvest with no silvicultural activities allowed (D)		
	Coef.	Rob. S.E	M.E	Coef.	Rob. S.E	M.E	Coef.	Rob. S.E	M.E
INC	0.002	0.003	0.002	−0.001	0.003	0.002	−0.002	0.004	−0.002
AGE	−0.002	0.005	−0.000	−0.000	0.006	−0.000	0.001	0.006	0.000
EDUC	0.356	0.390	0.107	0.250**	0.391	0.107	0.214	0.440	0.004
GENDER	0.267	0.176	0.081	0.278	0.191	0.081	0.407	0.211	0.091
PROFORG	0.262	0.145	0.079	0.348	0.155	0.079	0.135	0.163	0.030
ENVORG	−0.638	0.321	−0.019	−0.346	0.283	−0.019	−0.551	0.351	−0.124
FMP	0.429	0.165	0.130	0.383	0.164	0.130	0.228*	0.193	0.051
FAM.CRP	0.296	0.143	0.089	0.208	0.148	0.089	0.173	0.155	0.039
BID	0.002**	0.000	0.000	0.002**	0.000	0.000	0.002**	0.000	0.000
LEGACY	0.302	0.379	0.091	0.220	0.377	0.091	−0.361	0.403	−0.081
P.RECR	0.373	0.295	0.113	0.388	0.354	0.113	0.374	0.313	0.084
ESPRODN	−0.062	0.181	−0.019	−0.003	0.168	−0.019	−0.078	0.205	−0.017
FOREST SIZE	0.000	0.000	0.000	0.000*	0.000	0.000	0.000	0.000	0.000
INVEST	0.651**	0.360	0.197	0.462**	0.361	0.197	0.408**	0.392	0.092
Constant	−2.953	0.848		−2.456	0.834		−2.469	0.828	
Log likelihood	−338.99								
P-value	0.000								
atanhrho12	1.870**								
atanhrho13	1.350**								
atanhrho23	1.603**								
N = 336									

Coef.: Coefficient; Rob. SE: Robust Standard Error; M.E: Marginal Effect.

* Significant at 10%.

** Significant at 5% level.

Model 1 (Table 3), in which "unsure" responses were removed, showed that gender (GENDER) had an association with the probability of implementing the forest management alternative B with male forest landowners being 11% more likely to implement this alternative than female landowners ($p \le 0.10$). Members of professional organizations (PROFORG) were 17% more likely to implement management alternative C than non-members ($p \le 0.10$). A compensation level (BID) had a positive association with the probability of implementing all forest management alternatives ($p \le 0.05$). Marginal effects for alternatives B, C, and D were 0.10, 0.09, and 0.07, respectively, indicating that a for a 1% increase in a compensation level, probability of accepting these alternatives increased by 10, 9, and 7%, respectively. However, the marginal effect of a change in compensation level decreased when moving from a less restrictive forest management alternative to a more restrictive one indicating that family landowners were more likely to accept a less restrictive management alternative for the same marginal change in compensation level. Furthermore, landowners who rated a long-term investment (INVEST) as an important forest land ownership objective were more likely implement all proposed forest management alternatives ($p < 0.05$). Marginal effects for a long-term investment ownership objective were 36, 46, and 39% for alternatives B, C and D, respectively. Thus, a landowner who ranked a long-term investment as an important ownership objective was 32, 29, and 19% more likely to implement management alternatives B, C, and D, respectively, than a landowner who did not consider a long-term investment as an important ownership objective.

A model 1 results also indicated that annual gross household income (INC), age (AGE), and landowner education level (EDUC) did not have a statistical relationship with probability of implementing any of the three forest management alternatives ($p > 0.10$, Table 3). Similarly, membership in environmental organizations (ENVORG), possession of a written forest management plan (FMP), familiarity with CRP (FAM.CRP), personal recreational goal (P. RECR), previous management for ecosystem services (ESPRODN), and size of forest land area owned (FOREST SIZE) were not associated with the probability of implementing any of three forest management strategies ($p > 0.10$).

A compensation level and importance of a long-term investment as a forest ownership objective were also statistically significant in model 2 (Table 4), in which “unsure” responses were treated as “no” responses ($p \leq 0.05$). However, education and possession of a forest management plan which were significant in model 1, were not significant in the model 2 ($p > 0.10$). Remaining variables including age, household income, membership in environmental organizations, importance of personal recreation as a forest ownership goal, familiarity with CRP, and size of forest land area owned were non-significant in both models ($p > 0.10$).

Generally, required WTA compensation amounts increased with a higher level of forest management restrictions, both in models 1 and 2. The mean WTA compensation values were $190.22, $237.84, and $423.28/ha/year for forest management alternatives B, C and D, respectively, when unsure responses were removed from the analysis. Lower and upper bounds for the 95% confidence interval (CI) for alternative B were $144.50/ha/year and $244.48/ha/year, whereas values for alternative C were $182.17/ha/year and $323.79/ha/year, respectively. Lower and upper bound values for alternative D were $328.44 and $615.42, respectively. When “unsure” responses were treated as “no” responses, required compensation levels were substantially larger. The mean WTA compensation amounts were $374.12, $447.60, and $595.23/ha/year for implementing forest management alternatives B, C, and D, respectively. In addition, 95% CI for alternatives B, C, and D were $304.93 to $491.55/ha/year, $354.34 to $625.84/ha/year, and $469.05 to $862.95/ha/year, respectively. The covariance matrix indicated that multicollinearity was not a problem because none of the correlation values was > 0.65 (Table 5).

4. Discussion

An analysis of monetary compensation amounts required to implement forest management alternatives facilitating production of ecosystem services provides important information to various stakeholders including decision makers, federal and state conservation planners, budget managers, and government and non-governments conservation organizations (Butler, 2008). These stakeholders can make more informed conservation decisions and prioritize conservation efforts by knowing the potential monetary cost of producing ecosystem services, understanding landowner forest management preferences, identifying types of landowners who are likely to participate in conservation efforts, and being able to determine budgets needed to achieve specific conservation objectives (Buttoud, 2000).

Previous studies reported varying WTA amounts required by landowners to manage forests for ecosystem services (Timmons, 2014; Joshi et al., 2013; LeVert et al., 2009; Fletcher et al., 2009; Kilgore et al., 2008). The WTA compensation values obtained in this study were comparable to estimates reported in previous research including Fletcher et al. (2009) and LeVert et al. (2009). However, they were higher than the average amount of $33.00/ha/year offered by the existing Conservation Reserve Program (CRP) in Mississippi (USDA NRCS, 2014). Given the fiscal constraints experienced at the national level (Butler, 2008), it may be prudent to explore more efficient ways of using already existing budgets for conservation programs. For example, more than half of the U.S. Forest Service's budget meant for conservation purposes is usually allocated for fire-related activities in the United States (USDA NRCS, 2014). As such, improvements in fire control may also help to unlock some financial resources into other areas of natural resource conservation (Kilgore et al., 2008).

Based on this study's WTA estimates and the proportion of pine forest land under private ownership, the total cost of increasing production of ecosystem services by Mississippi's pine forests, ranged from $0.88 billion to $4.76 billion per year. This estimated cost of implementing forest management strategies to further increase production of ecosystem services is 28 to 150 times larger than the average annual CRP budget for Mississippi of about $32 million for conservation activities on approximately 344,000 ha (USDA NRCS, 2014). Consequently, the involvement of private sector and non-governmental organizations will be needed to improve financial resources available for conservation activities (Butler, 2008).

In terms of observed trends, the importance of long-term investment as a forest land ownership objective and compensation level were associated with willingness to implement forest management alternatives facilitating ecosystem services across both models. Landowners who considered their forest land as a long-term investment were more likely to implement forest management facilitating ecosystem services at all payment levels than landowners who perceived the long-term investment objective as unimportant. This result is consistent with Janota and Broussard (2008)'s analysis of landowners in southern Indiana indicating that investment goals represented an important determinant in landowner's choice of alternative forest policies, strategies, and programs. The finding highlights the relative importance that such landowner groups place on financial aspects of forest ownership (Kline et al., 2000) and implies that landowner groups who seek a financial return from their forest land have a greater likelihood of implementing forest management regimes if monetary compensation is offered. This may be related to a higher opportunity cost associated with the implementation of restrictive management regimes instead of prescriptions primarily focused on increasing a financial return (Janota and Broussard, 2008). Thus, it may be prudent to include strategies for improving financial aspects of forest ownership by incorporating additional income opportunities such as those related to hunting fees or creating recreational enterprises in incentive and outreach programs (USDA, NRCS 2014). For instance, an activity such as the establishment of quality wildlife habitat is important because it helps to increase the value of the land and financial returns to the landowner from fee hunting opportunities (Jenkins et al., 2010). Experiences in the United States, however, showed that some conservation programs administered through public agencies do not reflect the diverse ownership objectives of landowners (Jacobson et al., 2009). For example, a survey of landowners in Florida revealed that public agencies had programs for a few ecosystem services but these programs were not consistent with landowner objectives, which resulted in limited participation and negatively impacted an adoption of sustainable forest management strategies and production of ecosystem services (Taylor Stein et al., 2013).

Higher compensation levels were associated with a greater

Table 5
Mean willingness to accept (WTA) compensation values and 95% confidence intervals for forest management alternatives quantified using Krinsky-Robb procedure, based on a mail survey of family forest owners in Mississippi conducted in 2012.

	Forest management alternatives		
	Delayed harvest with all silvicultural activities allowed (B)	Delayed harvest with some silvicultural activities allowed (C)	Delayed harvest with no silvicultural activities allowed (D)
"Unsure" responses treated as "no" responses			
Mean/median WTA ($/ha/year)	374.12	447.60	597.23
95% CI	304.93–491.55	354.34–625.84	469.05–862.95
p-values for WTA = 0	0.00	0.00	0.00
"Unsure" responses removed			
Mean/median WTA ($/ha/year)	190.22	237.84	423.28
95% CI	144.50–244.48	182.17–323.79	328.44–615.42
p-values for WTA = 0	0.00	0.00	0.00

probability of implementing forest management strategies promoting ecosystem services, both in models 1 and 2. This finding is consistent with many previous studies (Joshi et al., 2013; Broch et al., 2013; Gruchy et al., 2012; Convery et al., 2012; Kilgore et al., 2008; Mozumder et al., 2007; Kreuter et al., 2006) which indicated that financially motivated landowners might not adopt proposed forest management regimes focused on ecosystem services if monetary incentives were not available (Matta et al., 2009; Nahuelhual-Muñoz et al., 2004). The implication of this finding is that monetary incentives may have to be used as a strategy for increasing implementation of conservation activities and producing more ecosystem services by forest landowners in the future programs.

Findings also indicated that average WTA amounts increased with a greater level of forest management restrictions. The trend associated with forest management restrictions is consistent with Kreuter et al. (2006), Janota and Broussard (2008) and Matta et al. (2009), who showed that landowners preferred forest management with fewer limitations because such management was less likely to interfere with their ownership goals. This finding suggested that forest management prescriptions featuring fewer restrictions are more likely to be accepted by family forest landowners. On the other hand, sustainable forest management practices that limit landowner management options might still be feasible but might be costlier to implement because of higher monetary compensation required by landowners (Kreuter et al., 2006).

Gender had a significant relationship with probability of implementing the proposed forest management alternatives with male landowners being more likely to implement these strategies (model 1). This finding may be linked to the observation that male landowners represented about 80% of the sample size. A strategy that targets male landowners by providing appropriate information on conservation programs is, therefore, likely to enhance the adoption of best forest management practices because they constitute approximately 90% of the forest family landowners in the southern United States (USDA Census of Agriculture, 2007). However, it is also important to include female landowners in this effort because they constitute an increasing proportion of forest landowners in the United States (Warren, 2003).

Professional organizations can play an important role in promoting conservation activities focused on ecosystem services as forest owners who were members of professional organizations were more likely to implement forest management facilitating ecosystem services than non-members (model 1). There were more landowners who were members of professional organizations than non-members which could explain the significance in model 1. Efforts to increase implementation of conservation might thus focus on increasing landowner awareness through participation in professional associations (Rickenbach et al., 2006). This may involve providing information through various professional outlets such as newsletters including information on alternative forest management strategies promoting protection of natural resources and simultaneously enhancing the production of multiple ecosystem services (Mozmuder et al. 2007).

Membership in environmental organizations, possession of a written forest management plan, and familiarity with CRP did not display a relationship with the implementation of forest management alternatives. While this finding is not consistent with previous studies, it could be attributed to the observation that, in general, relatively few landowners were members of environmental organizations, owned written forest management plans, or were familiar with CRP (Rickenbach, 2009; Hughes et al., 2005).

Similarly, landowner socioeconomic characteristics including annual gross household income, education, and age were not related to implementation of forest management alternatives facilitating ecosystem services (model 1). This finding is different from previous studies which reported that landowner socioeconomic variables such as education and income were important determinants of landowner decisions related to WTA compensation (Gruchy et al., 2012; Grutters et al., 2008; Kennedy, 2001). This finding might potentially be attributed to the algorithm used by the "cmp" routine which uses observations where at least one of the dependent variables is observed and might lead to insignificant variables in the case of missing data (Roodman, 2011). The fact household income was not statistically significant suggested that while many landowners considered their property as a long-term investment, some of the benefits derived from the property were non-monetary (Grebner et al., 2013). These benefits may be consistent with landowner recreational goals including clean air, pollution control, hunting, and fishing (Grebner et al., 2013). Thus, landowner choices depended, to a large extent, on the characteristics of each forest management alternative such as the intensity of forest management restrictions and offered compensation level. Timber production-oriented landowners might require higher compensation levels for implementing restrictive forest management regimes to offset potential revenue losses. However, landowners with non-timber ownership objectives might be willing to accept lower compensation levels or implement management prescriptions facilitating ecosystem services at no cost to the conservation program if provided with suitable technical and outreach assistance, especially if these prescriptions enhance their forest management objectives.

Importance of personal recreation as a forest ownership goal, previous forest land management for ecosystem services, and total size of forest land owned were also insignificant explanatory variables for landowner decisions related to implementation of forest management alternatives facilitating ecosystem services. Previous studies such as Gruchy et al. (2012) and Nahuelhual-Muñoz et al. (2004) also showed that these variables were not statistically significant. One possible explanation might be that landowners who used their forest land for recreation might not have an incentive to implement other silvicultural prescriptions which may impede their primary ownership goals

(Hedlund, 2011) and, therefore, such landowners were less likely to implement forest management strategies associated with multiple ecosystem services. Similarly, landowners who previously managed their forests for ecosystem services might not be willing to participate in proposed management alternatives because they already committed their forests to producing different outputs (Main et al., 1999). This may imply the need to focus future programs on landowners who may have not previously participated in conservation programs. While the size of forest land owned was not associated with landowner willingness to implement forest management alternatives, it influences types of management prescriptions to be implemented as well as their costs and, thus, can affect production of ecosystem services (Grebner et al., 2013).

This study has limitations that should be addressed in future research to obtain more precise estimates of a potential cost to increase production of ecosystem services across different forest types. The study derived cost estimates of increasing production of ecosystems services in pine stands intensively managed for timber production and these estimates do not necessarily reflect the cost of facilitating ecosystems services in more diverse forest types such as hardwood and mixed pine-hardwood forests, which typically require more complex management prescriptions but also provide a greater variety of ecosystem services. Owners of hardwood and mixed pine-hardwood forests often have multifaceted ownership objectives which often align well with production of ecosystem services and, therefore, they might require lower compensation levels and/or different types of assistance. Moreover, the contingent valuation scenario in this study used WTA approach which helped approximate the cost and potential budgets necessary to increase production of ecosystem services but represented a less conservative estimate than the WTP approach. Thus, a further research is needed to quantify the public's WTP for ecosystem services which will be helpful in determining budgets necessary to identify most suitable policies to achieve specific levels of conservation efforts and ecosystem service production, improve budget allocations, and prioritize conservation efforts from a public perspective.

5. Conclusions and policy implications

This study increased an understanding of landowner preferences concerning financial compensation needed to implement forest management alternatives increasing production of multiple ecosystem services. The research also identified socioeconomic factors that were associated with landowner willingness to implement these management alternatives. Such information is important for decision makers and budget managers as it helps quantify the cost of attaining specific conservation objectives.

Mississippi has potential for increasing production of ecosystem services from private lands because a substantial proportion of landowners managing their pine stands for timber production were willing to implement forest management facilitating ecosystem services at offered compensation levels. Minimum and maximum compensation levels required to induce landowners to adopt forest management alternatives facilitating production of ecosystem services were $190.22/ and $595.23/ha/year, respectively, and corresponded to total monetary cost of $0.88 billion to $4.76 billion, which represented a potential budget necessary to implement forest management practices facilitating ecosystem services in Mississippi. Production of ecosystem services requiring substantial restrictions or modifications in forest management will require higher compensation levels than less restrictive forest management alternatives. However, the implementation of conservation practices by landowners is constrained by a limited CRP budget. Thus, if future conservation initiatives are to be successful, they must be flexible in terms of forest management restrictions, target both male and female landowners, and incorporate landowner ownership objectives.

By accounting for the monetary cost necessary to facilitate production of ecosystem services, the outcomes from this study contributed to extant literature on contingent valuation of ecosystem services. This is because most previous studies focused on single or separate ecosystem services, whereas this study determined the costs associated with implementing forest management facilitating multiple and stackable ecosystem services.

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